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Performance Assessment of Hazardous Air Pollutant (HAP)–Free Chemical Paint Strippers on Military Coatings for Validation to Federal Specification TT-R-2918A

by Lindsey Blohm, Alicia Farrell, and John Kelley

NOTICES

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14. ABSTRACT

The US Army Research Laboratory was tasked with evaluating hazardous air pollutant (HAP)–free alternative paint strippers for validation to Federal Specification TT-R-2918A. One of the major obstacles in finding suitable “drop-in” replacements for methylene chloride is that most HAP-free products have been known to have slower paint removal times. Strip time and performance are important considerations in high-volume operations. The results presented in this report represent the performance of the HAP-free strippers versus a control formula remover in accordance with procedures outlined in Federal Specification TT-R-2918A on both Navy and Army coating systems. The results indicate that some of the alternative strippers performed well compared with the control and the methylene-chloride-based product. One product had performance comparable to that of methylene chloride, removing nearly 100% of all paint layers from the test panels. Depending on the stripping application and coating systems, some of the products tested are considered viable alternatives to methylene chloride strippers.

15. SUBJECT TERMS

methylene choride, depainting, paint stripping, hazardous air pollutant, TT-R-2918A

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1. Introduction

Methylene chloride (dichloromethane) is a widely used chemical solvent with a diverse number of applications. It was introduced as a replacement for more-flammable solvents more than 60 years ago and is commonly used in paint removers and industrial adhesive applications.[1] Methylene chloride is an organic solvent that is especially effective as a paint remover. However, overexposure can cause serious health problems. Like many organic solvents, methylene chloride can damage the brain, skin, lungs, and other organs. In addition, it has been shown to cause cancer in humans and laboratory animals.[2] For this reason, the Occupational Safety and Health Administration reduced its allowable exposure limits from 500 ppm in an 8-h time-weighted-average (TWA) period in 1971 down to 25 ppm TWA for 8 h, or 125 ppm for shorter-term exposure in a 15-min sampling effective in April 1997.[3] Additionally, the National Institute for Occupational Safety and Health recommends that exposure to methylene chloride in the workplace be limited to the lowest feasible limit, and the American Conference of Governmental Industrial Hygienists recommends a workplace exposure limit of 50 ppm averaged over an 8-hr day.[4]

The effects of methylene chloride are not limited to the health implications caused in the workplace. It has also been identified as a hazardous air pollutant (HAP) by the US Environmental Protection Agency (EPA). In fact, the EPA will be introducing a series of new National Emission Standards for Hazardous Air Pollutants that will likely impact current operations within the US Department of Defense (DoD) and industry as a whole.[5]

The US Army Research Laboratory has been tasked with evaluating HAP-free alternative paint strippers for validation to Federal Specification TT-R-2918A.[5] One of the major obstacles in finding a suitable "drop-in" replacement for methylene chloride is that most HAP-free products have been known to have slower stripping times than those that contain methylene chloride. Strip time and performance is an important consideration in high-volume operations.

The information presented in this report represents the results of laboratory performance evaluations of the HAP-free strippers versus a control formula remover in accordance with procedures outlined in TT-R-2918A.[6] Table 1 lists available chemical paint strippers.

Table 1 Chemical paint strippers

Product trade name	Manufacturer	Process	Contents	pH
Dekote	Eastwood	Benzyl alcohol	Benzyl alcohol (<45%), aromatic hydrocarbon (1) (5%–15%), hydrogen peroxide (<15%), dioxolane (<16%), water (>20%)	5.5–6.0
D-Zolve 15–33	Solvent Kleene	Benzyl alcohol	Alkyl methyl ester, petroleum naptha, benzyl alcohol, methyl phenyl ether	10.5
Socostrip A0103N	Socomore	Benzyl alcohol	Benzyl alcohol, hydrogen peroxide solution, hydrocarbons (C10–C13, N-Alkanes, isoalkanes, cyclic, <2% aromatics), 2-(2-heptadec-8-enyl-2-imidazol-in-1-yl)ethanol	6.90
Ardrox 2871	Chemetall	Benzyl alcohol	Benzyl alcohol	6.0–7.0
TURCO 6813E	Henkel	Benzyl alcohol	Benzyl alcohol (30%–60%), anisole (10%–30%), amine borate (1%–5%), benzene (C10-16-alkyl derivatives) (1%–5%), ammonium hydroxide (1%–5%), 2 methylbut-3-yn-2ol (1%–5%)	10.0–10.8
B&B 9095N	B&B TRITECH	Benzyl alcohol	Benzyl alcohol (<50%), aromatic hydrocarbon (<5%), hydrogen peroxide (<10%)	6.4–7.0
Desolift 5269	PPG	Benzyl alcohol	Benzyl alcohol, hydrogen peroxide, barium bis dinonylnaphthalenesulphonate	5.0
PPG Aerospace PR-3500	PPG	Methylene chloride	Methylene chloride (30%–60%), phenol (10%–30%), sodium dichromate, dehydrate (<5%)	. . .

2. Experimental Procedure

Aluminum alloy 2024-T3 panels approximately 4 × 12 inches, pretreated with Alodine 1200S according to MIL-C-5541[7] Class 1A, were selected as the substrate material. All aluminum panels were cleaned until free of debris, oily film, and corrosion according to Federal Specification TT-C-490F.[8] Primer was applied to one side of each panel with a test coating of uniform thickness. The panels were left to dry overnight under standard ambient conditions. The panels were painted according to a modified version of ASTM D6189-94[9] according to the stack-up described in Fig. 1. Panels were primed with MIL-PRF-23377 Class 2,[10] MIL-PRF-85582 Class 2,[11] and MIL-DTL-53022 Type IV.[12] All panels were then top-coated with 2 distinct layers of MIL-DTL-64159 Type 2.[13] The topcoat layer colors were alternated between 686 tan and 383 green to make the

stripping evaluations easier to quantify. A schematic of each of the chemical-agent-resistant coating (CARC) painted panels is shown in Fig. 1. The top layers of topcoat are tan and the bottom layers of topcoat are green. After the panels had the total coating systems in place, they were air dried for approximately 168 h and then postcured for approximately168 h at 65.5 °C (150 °F).

Coating System Stack-up		
1	Topcoat (tan)	MIL-DTL-64159 TYPE II
	Topcoat (green)	MIL-DTL-64159 TYPE II
	Primer	MIL-DTL-53022 TYPE IV
2	Topcoat (tan)	MIL-DTL-64159 TYPE II
	Topcoat (green)	MIL-DTL-64159 TYPE II
	Primer	MIL-PRF-23377 TYPE II Class C2
3	Topcoat (tan)	MIL-DTL-64159 TYPE II
	Topcoat (green)	MIL-DTL-64159 TYPE II
	Primer	MIL-PRF-85582 TYPE I Class C2

Fig. 1 Coating system stack-up on chromated aluminum test panels

2.1 Manual Stripping Experiment

For evaluation, an "X" 1.0 inch in length was scribed in the center of each panel on the coated surface side using a tungsten carbide stylus, ensuring that the scribe cut through the coating to the substrate. The edges of the prepared test panels were sealed with beeswax by dipping the panels to a depth not exceeding 6 mm (0.25 inch) on all edges.

2.2 Control Formulation

The control formula remover was prepared by mixing the ingredients listed in Table 2 in a high-speed blender. This formula is as described in Federal Specification TT-R-2918A 4.6.3.4.1.[6]

Table 2 Formula for control paint remover

Ingredient	wt%
Anisole	19.0
Methocel, grade F4M 1/	1.32
Benzyl alcohol	41.7
Water	33.2
Ammonia	4.78

Mixing instructions for a 500- or 1,000-g batch are the following:

1. Weigh out anisole.
2. Weigh out methocel on filter paper and slowly add to the anisole while stirring with an impeller-type mixer until a smooth consistency is produced.
3. Weigh benzyl alcohol into the mix and stir at full speed until homogeneous.
4. Weigh out water into a separate container.
5. Weigh 28% ammonia into the water and stir for a few seconds with a spatula.
6. Add 50-g increments of the mixture from number 5 to the mixture from number 3 while blending at high speed. Blend after each addition to produce a smooth milkshake consistency. Complete the formula preparation in less than 5 min to avoid loss of ammonia.

2.3 Test Setup

The panels were racked at an angle of approximately 60° to horizontal in accordance with Federal Specification TT-R-2918A 4.6.3.4.1[6] (Fig. 2). Once racked, the angle was measured using a protractor. Six test panels (2 for each coating combination) were placed on a rack with the coated and scribed side surface up.

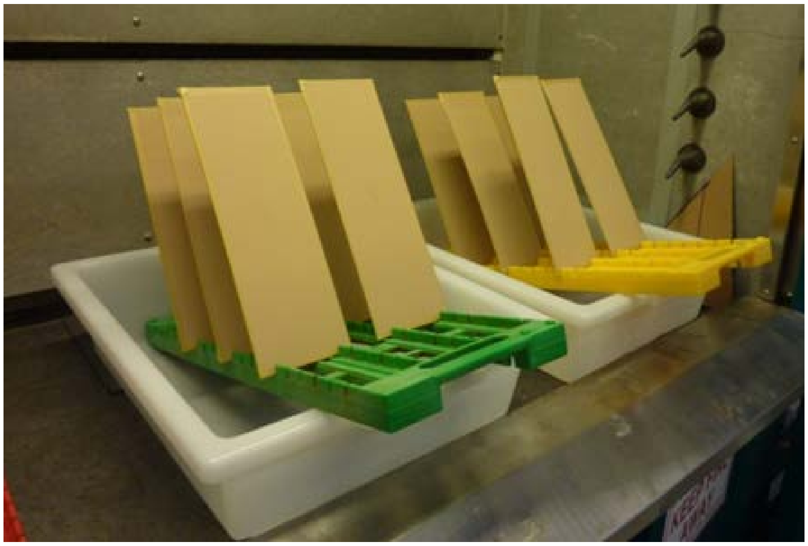

Fig. 2 Panels set at 60° from horizontal prior to application of paint strippers

The remover was applied by pouring it along the top edge of the test panels as shown in Fig. 3. The paint remover was then allowed to flow down the front face of the panel, taking no longer than 1 min to coat the sample. The remover was allowed to dwell on the panels for 4 h prior to scraping.

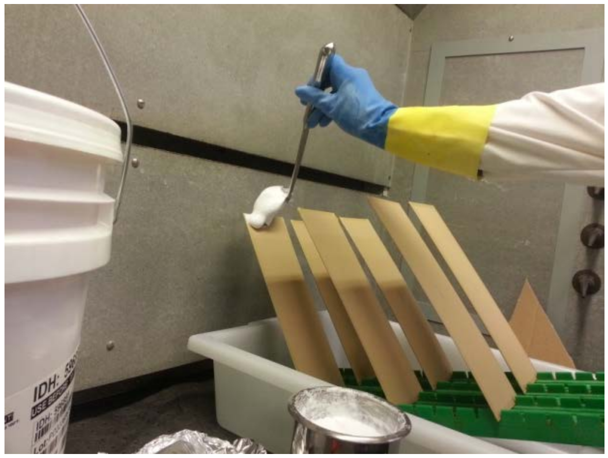

Fig. 3 Application of paint stripper. The paint stripper was poured over the panels and allowed to run down and cover the panel completely.

After the dwell time of 4 h, each panel was scraped using a rigid high-density polyethylene plastic scraper (Fig. 4) to remove any loosened coating and the remaining paint remover. The test panels were placed back on the racks, and additional remover was applied as previously described. The second application of paint remover was allowed to dwell on the panel for an additional 4 h.

Fig. 4 Plastic Klean Strip high-density polyethylene scraper

Following the second application of paint remover, the panels were again scraped using the rigid plastic scraper to remove any additional loosened coating and paint remover residue. The test panels were then rinsed with tap water and brushed with a soft nylon-bristle brush. This procedure was again conducted in accordance with TT-R-2918A.[6]

2.4 Evaluations

The evaluations of the test panels were performed 2 ways. The first evaluation was performed using a 200-grid rectangle on transparent film overlaid on each panel to help estimate the percent coating removed (Fig. 5). The grid was placed over the

test area, and the percentage of painted area removed was determined. This type of grid is commonly used in estimating percent area for corrosion panels according to ASTM 1654.[14] In addition, each panel was scanned for image evaluation. ImageJ software[15] was used to more accurately determine the amount of coating removed from each panel. The pixel area of each panel was measured with the tracing tool, as was the pixel area of paint removed. Per each pair of panels, the area of the overall panel was averaged to find the area of paint removal of each panel. The average paint removal of each pair of panels was calculated, and the results were plotted. The ImageJ results are reported in Section 3.

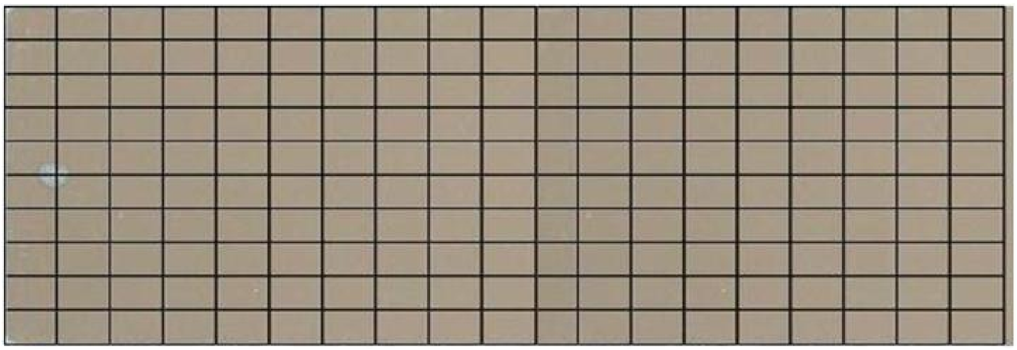

Fig. 5 Example of a CARC-coated test panel with overlaid evaluation grid

3. Results and Discussion

The results from the manual stripping experiments are presented in Figs. 6–11. Figures 6, 8, and 10 are the performance ratings. The photographs shown in Figs. 7, 9, and 11 are examples of the baseline aerospace formulation, the control formula, and the best and worst performers of the coating stack-up, respectively. The stripping performance of several of the alternative HAP-free products was comparable to the only methylene chloride depainter tested, PPG PR-3500. In Fig. 6 is the rated performance of the strippers versus coating system 1, the Army CARC MIL-DTL-64159[13] topcoat with MIL-DTL-53022 primer.[12] Dekote and Socostrip showed very good performance and removed as much of the primer as it did the topcoat. In fact, all strippers removed the coating system as a whole, leaving no residual MIL-DTL-53022 primer. Desolift was the least successful with an average of 47.6% total removal. This set of panels had the most inconsistent results; one panel had no removal and the other had nearly 100% removal. In general, for this coating system, removal was achieved at the substrate and not between the primer and topcoat. Where paint was removed, it came off in sheets with little to no scraping. Panels treated with the PPG Aerospace, control formula, Socostrip A0103N, and Desolift 5269 strippers are shown in Fig. 7.

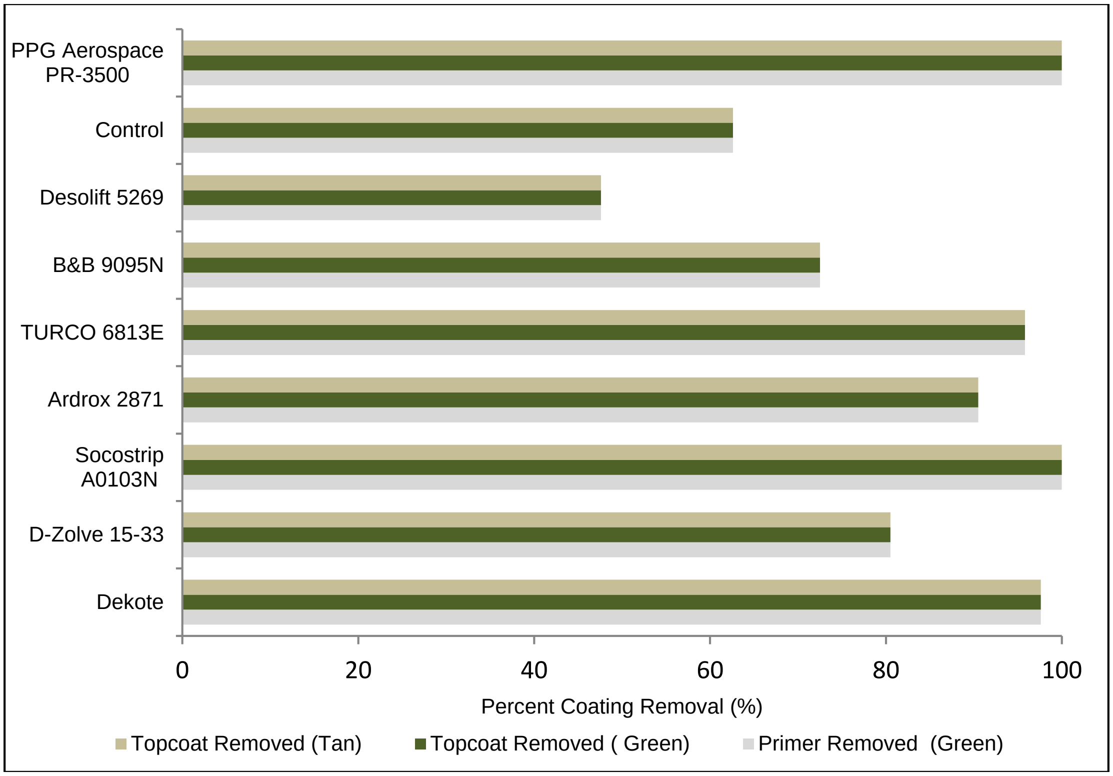

Fig. 6 Performance of paint strippers on coating system 1: CARC MIL-DTL-53022 primer with MIL-DTL-64159 topcoat

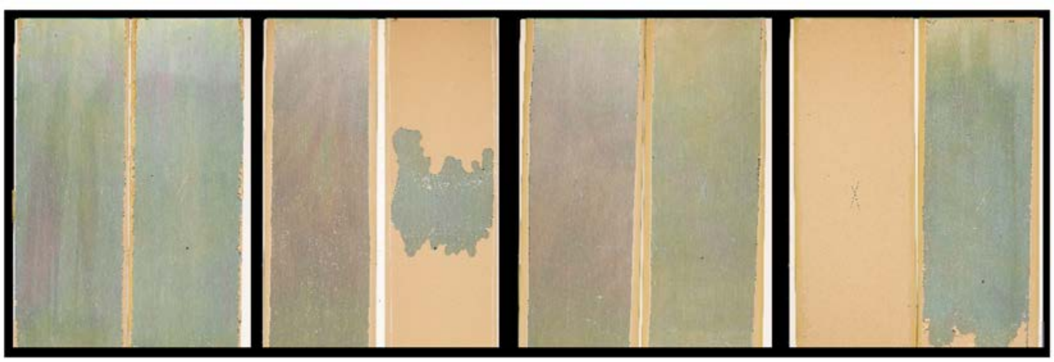

Fig. 7 (left to right) PPG aerospace, control formula, Socostrip A0103N, and Desolift 5269 as tested on coating system 1

Figure 8 shows the performance of the strippers versus coating system 2, the Army CARC topcoat MIL-DTL-64159[13] with MIL-DTL-23377 primer.[10] Figure 9 displays scans of 4 pairs of panels, including the PPG (methylene chloride), control, Dekote (best performer), and D-Zolve (worst performer). Overall, the paint strippers had the most difficultly removing this coating system. Only 3 strippers had any success in removing the MIL-DTL-23377 primer: PPG Aerospace (methylene chloride), Socostrip, and Dekote. As expected, PPG removed 100% of

the entire coating system. The control formula, however, was completely ineffective with 0% coating removal. The bubbling around the X-scribe of the D-Zolve panel occurred only after some unmeasured amount of time following the rinsing process. This happened multiple times throughout the testing, where there was lifting/peeling after rinsing and drying in the following days of the depainting process. Dekote and Socostrip are the only HAP-free options capable of sufficiently removing this coating system down to and including the primer.

Fig. 8 (left to right) PPG Aerospace, control formulation, Dekote, and D-Zolve 15-33 as tested on coating system 2

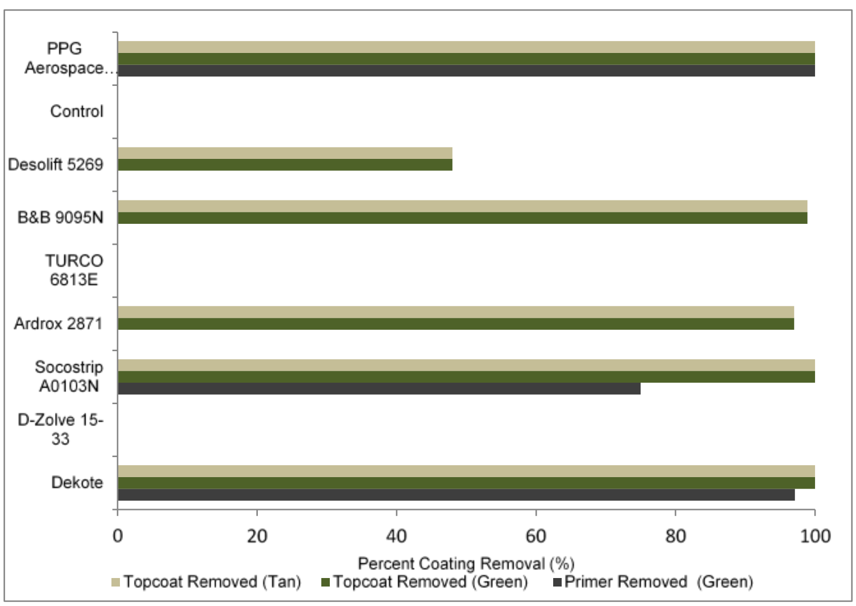

Fig. 9 Performance of paint strippers on coating system 2: MIL-PRF-23377 primer with MIL-DTL-64159 topcoat

Figure 10 represents the performance of the strippers on coating system 3: the Army CARC topcoat MIL-DTL-64159[13] with MIL-DTL-85582 primer.[11] Figure 11 displays scans of 4 pairs of panels including the PPG (methylene chloride), control, TURCO 6813E (best performer), and Desolift 5269 (worst performer). Against coating system 3, TURCO had the best coating removal; however, with the

exception of Desolift, all of the alternatives were capable of sufficiently removing this coating system down to and including the primer. In some cases, where there was residual primer left on the panel after stripping, the primer that remained appeared grainy. This was especially evident in the case of Dekote, B&B, and Ardrox. The grainy primer had a rough sandpaper-like texture but remained firmly adhered to the substrate. Other than the PPG product, the only 2 alternative paint strippers that removed the primer with the topcoat in sheets were TURCO and D-Zolve. The topcoat lifting on the Desolift panels shown in Fig. 11 came after rinsing and drying and was not removable with scraping within the parameters of the testing process.

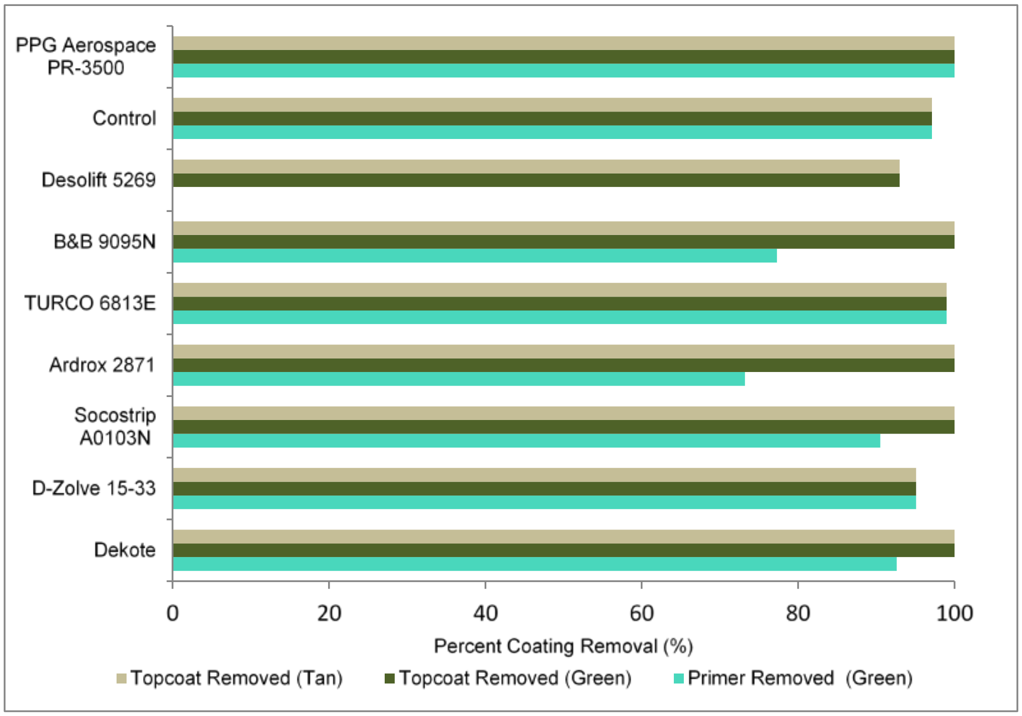

Fig. 10 Performance of paint strippers on coating system 3: MIL-PRF-85582 primer with MIL-DTL-64159 topcoat

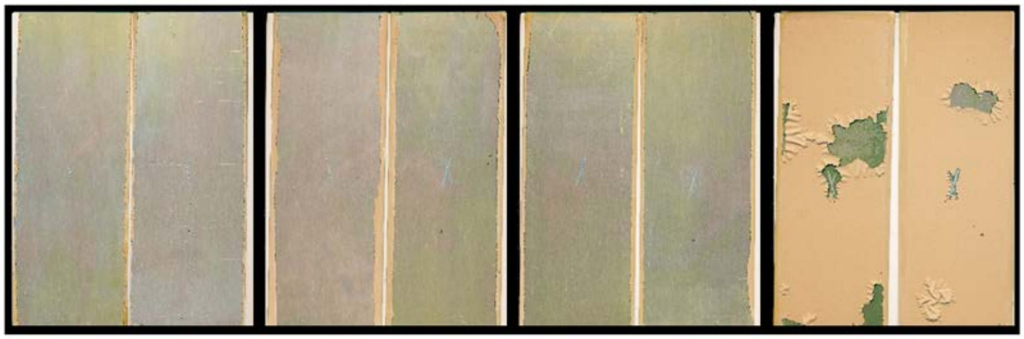

Fig. 11 (left to right) PPG aerospace, control formulation, TURCO 6813E, and Desolift 5269 as tested on coating system 3

Using the control formula as the baseline, each coating system was rated based on its total coating removal, with green as exceeding the control performance, red indicating that the remover did not meet the control performance, and gray indicating performance as good as the control (Table 3). As expected, the PPG (methylene chloride) depainter excelled at removing all 3 of the coating systems, but many of the alternatives also exceeded the control performance. Five of the removers (D-Zolve, Ardrox, TURCO, B&B, and Desolift) were unable to remove any of coating system 2, which used the 23377 primer. Socostrip had the best removal for coating system 1, Dekote for coating system 2, and TURCO for coating system 3. Desolift 5269 was clearly the weakest, unable to exceed the control against any of the coating systems. Overall, Dekote was the most consistent of all the alternatives at removing all 3 coating systems. Although it did not exceed the control formulation on coating system 3, it was capable of achieving 93% removal compared with the control's 97%.

Table 3 Percent clear pass/fail comparisons based on control performance

Remover	Coating system 1 (%)	Coating system 2 (%)	Coating system 3 (%)
Control	**62.6**	**0**	**97.1**
Dekote	**97.6**	**97.1**	**92.6**
D-Zolve 15–33	**80.5**	**0**	**95.1**
Socostrip A0103N	**100**	**75**	**90.5**
Ardrox 2871	**90.5**	**0**	**73.2**
TURCO 6813E	**95.8**	**0**	**99**
B&B 9095N	**72.5**	**0**	**77.3**
Desolift 5269	**47.6**	**0**	**0**
PPG Aerospace PR-3500	**100**	**100**	**100**

Note: green = exceeds control performance; red = remover did not meet control performance; gray = performance as good as the control.

4. Conclusions and Recommendations

Although products containing methylene chloride are very effective at removing organic coatings, several of the HAP-free paint strippers were shown to be viable alternatives as validated in accordance with TT-R-2918A[6] on 3 DoD paint systems. Many of the strippers were comparable and excelled beyond the control formula. Dekote was the best all-around stripper, performing well across all 3 coating stack-ups, including removing the most difficult coating systems with MIL-PRF-23377[10] primer. The effectiveness of most of the alternatives varied across the coating systems tested. The use of any one of the alternatives would likely be application-specific and depend on the coating system to be removed.

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List of Symbols, Abbreviations, and Acronyms

CARC	chemical-agent-resistant coating
DoD	Department of Defense
EPA	Environmental Protection Agency
HAP	hazardous air pollutant
TWA	time-weighted average

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